MULTI-TECHNIQUE STUDY OF A MARTIAN AEOLIAN SAND ANALOG

K. R. Kuhlman[1], J. Marshall[2], N. D. Evans[3], and A. Luttge[4] (1) Jet Propulsion Laboratory, MS 302-231, Pasadena, CA, 91109; kkuhlman@jpl.nasa.gov, (2) SETI Institute, Moffett Field, CA (3) Oak Ridge National Laboratory, Oak Ridge, TN (4) Rice University, Houston, TX.

Development of *in-situ* versions of scientific instruments that we often take for granted on Earth is especially difficult due to the limitations in power, mass, volume and human interaction for robotic missions. The Mars Environmental Compatibility Assessment (MECA) was perhaps the most capable suite of scientific instruments yet developed for *in-situ* deployment [1]. It combined optical and atomic force microscopy (AFM), wet chemistry, electrometry and various other analytical capabilities. Here we illustrate some of the types of data that might be returned in the future from technological advances in microscopy as well as benchmarking currently available *in-situ* measurements. To demonstrate potential scientific and technical merits of *in-situ* microscopy on Mars, we analyzed a possible Martian regolith analog -- an aeolian red dune sand from the central Australian desert (near Mt. Olga) [2]. A database of detailed studies of such terrestrial analogs would assist the study of geological and astrobiological specimens in future missions to Mars.

A companion abstract [1] demonstrates the capability of the MECA suite using the same Martian analog. While these instruments would have provided exciting new understanding of the Martian dust, much needed information would have been missed. Concepts for *in-situ* instruments that are currently under development by NASA for deployment on Mars include local electrode atom probe nanoanalysis (LEAP), vertical scanning white light interferometry (VSWLI) [3], scanning electron microscopies and energy dispersive x-ray microanalysis (EDX). While *in-situ* deployment of these techniques is many years away, ground-based studies using these analytical techniques extend our understanding of the data obtained from instruments to be flown in the near future.

Optical microscopy will be one of the first techniques used to observe Martian dust. However, optical microscopy suffers from narrow depths of field at high magnifications. Pseudoconfocal microscopy is a technique which takes advantage of the lack of depth of field to produce "in focus" optical images, such as shown in Figure 1. This image was produced using a stack of 32 images taken at a magnification of 100X and a depth of field of approximately 14 micrometers. The images were then deconvolved and combined using the Extended Focal Imaging (EFI) module in the analySIS® 3.1 software package from Soft Imaging System Corporation [4]. The image illustrates the non-uniformity of the red-orange coating and shows that there is a coating on every grain.

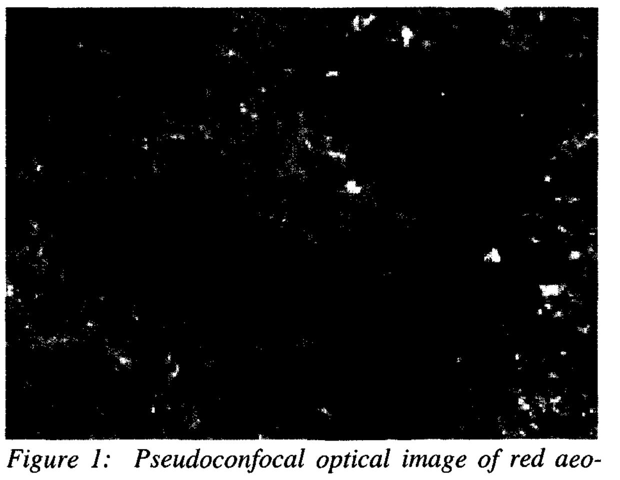

Figure 1: Pseudoconfocal optical image of red aeolian sand produced using a stack of 32 images. Magnification = 100 X. Background is frosted glass.

Another potential flight technique, vertical scanning white light interferometry (VSWLI) [3], provides about 0.5 to 1.5 micrometer lateral resolution and near atomic scale vertical resolution on the order of two nanometers for surface features up to 100 microns high. This technique rivals the atomic force microscope (AFM) in the high-resolution measurement of surface morphology while having the capability of measuring large surface areas. The three-dimensional image in Figure 2 illustrates the capability of this technique. This image also shows the difference in surface texture of one of the coated grains. Note the smooth texture on the left of the image and the rough texture on the right. This may indicate the difference between an abraded surface (left) and a surface that is coated (right).

Scanning electron microscopy (SEM) is one of the analytical techniques that are often taken for granted on Earth, but extremely difficult to implement *in-situ*. When combined with an energy dispersive x-ray spectrometer (EDX), this technique can reveal surface morphology and chemical composition on the scale of micrometers. This technique is very important for understanding the deposition of these surface coatings and modification by aeolian processes. Backscattered electron (BSE) images provide compositional data since backscattered yield is a function of atomic number. Surface weathering and the nature of the underlying particle can also be ascertained from the fractures in the surface as indicated by the arrow in Figure 3. Energy dispersive mapping of a cross-section shows that the coating (on the right of the BSE image in Figure 4) contains both iron and aluminum (Figure 5). These data appear to indicate that the film may be Al-substituted hematite, a cermet coating that is may have originated from clays in the region. The clays may have been dissolved by water during brief periods of precipitation, and percolated through the soil leaving evaporites in the crevices of the particles. The EDX spectra also indicate the presence of O, K, P, Ca, Ti, Cr, Ni, Zn, Cu and Au.

Figure 2: Vertical scanning white light interferometry (VSWLI) reconstruction of the surface of a coated grain. Note the differing textures between the left and right of the image.

Preliminary transmission electron microscopy (TEM) of a cross-section of one of the particles of red sand shows that the film is not uniform. In fact, the film appears to be composed of tiny crystalline grains within a matrix. The structure observed may be a result of fracture by aeolian processing followed by the "glueing" of the crystalline remnants to the surfaces of grains by the Al-substituted hematite cermet.

Ground-based measurements of terrestrial analogs with these and other techniques will further our understanding of the processes occurring on Mars and allow us to better understand the observations made by instruments to be flown in the near future. These results of these measurements also provide us with incentive to miniaturize these instruments for use both in remote deployment and as field equipment for future human explorers of Mars.

References: [1] Marshall, J. *et al.*, this volume, [2] Collected by Carol Breed, USGS, 1980, [3] Luttge, A. et al. (1999) *American Journal of Science*, **299**(7-9) 652-678, [4] http://www.soft-imaging.com/.

Research at JPL and SETI was sponsored by NASA. Research at the ORNL SHaRE User Facility was sponsored by U.S. DOE, under contract DE-AC05-00OR22725 with UT-Battelle, LLC, and through the SHaRE Program under contract DE-AC05-76OR00033 with Oak Ridge Associated Universities.

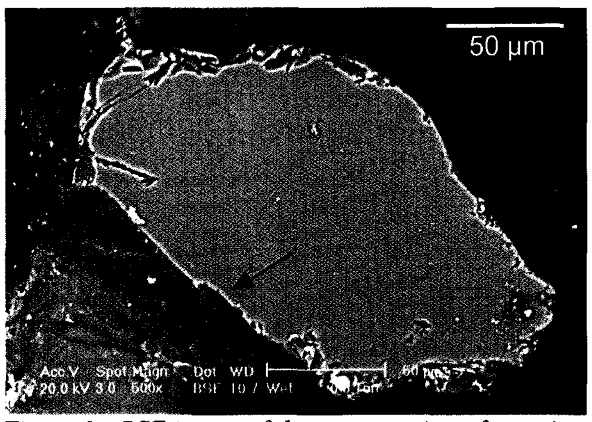

Figure 3: BSE image of the cross section of a grain of the analog sand showing fractures and cracking at the upper left edge from aeolian transport. Note the broken film at lower center just below the conchoidal fracture indicated by the arrow.

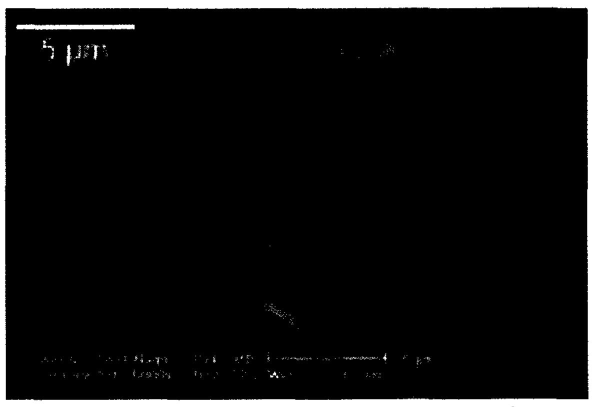

Figure 4: BSE of cross section of "red sand" grain showing texture of the coating. The polished cross-section of the quartz particle is on the left. Note the bright "grains" within the film that appear in the Fe image below.

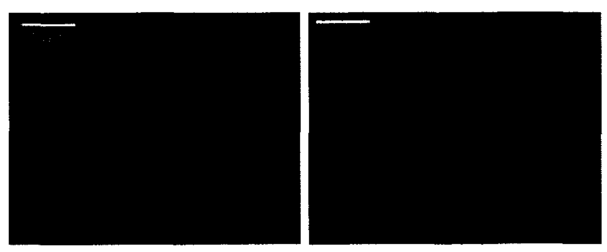

Figure 5: (a) Iron and (b) aluminum EDX maps of cross section in Figure 4. Note that the iron and aluminum coat the outer surface of the grain.